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Progress Report of Studies on Artificial Lighting of Dairy Stables.

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The purpose of the tests herein described was to obtain further information on the best arrangement of lamps for use in lighting dairy stables and to determine present farm practices. A survey of the natural lighting of farm barns was also made and will be reported at a later date. In these studies the Departments of Agricultural Engineering and Dairy Husbandry of the University of Maryland cooperated with the Divisions of Farm Structures Research and Rural Electrification Research 3/ of the Bureau of Agricultural Chemistry and Engineering of the United States Department of Agriculture.

More than 60 Maryland farm barns were visited and 25 of these were studied with 50 or more different light combinations ranging from 25 to 200 watt lamps, and with lamps spaced from 3 to 6 stalls apart. The farm combinations were then analyzed and new ones tried at the experimental dairy barn at the University of Maryland.

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Instruments

A standard type of Weston Light Meter having 0-25, 0-50, 0-250 scale ranges and a two-cell paddle with an extension cord was used. Special cover plates or screens were made so as to obtain daylight readings. A convenient, light-weight tripod was made for the light meter. A handle four feet long permitted the operator to vary his position so as to avoid shadows and to facilitate quick movement. The tripod had a fixed height of one foot and all floor readings were taken at this height. In the use of this instrument there is of course an element of personal error in reading and at the illuminations below a half footcandle the error in reading becomes larger. These data are presented without any attempt to make corrections for calibrations of instrument and should be accepted as such. Since for the most part the instrument was read and the paddle held by the same individuals, the personal errors are assumed to compensate.

Description of Stables

With the exception of 4 stables, all cows faced outward. Heights of lamps from the floor varied from 6 feet 6 inches to 12 feet. Stable widths varied from 32 to 47 feet (with 3 rows of cows) some with raised feed alleys and others with high front mangers. Lamp sizes in farm barns varied from 25 to 200 watts. Bare lamps, diffusion globes, shallow dome and concealed reflectors as well as angle reflectors from side walls were observed in farm barns. Many other interesting comparisons were made but time does not permit their discussion.

Since the Maryland University barn varied somewhat from the

ordinary farm barn, a brief record of the points of difference will permit of greater appreciation of the test data.

The barn walls were made of 8-inch concrete blocks, and beaded ceiling was used; both walls and ceiling were painted white but the surface had been somewhat dimmed by service. However, except for newly painted or freshly cleaned surfaces, the conditions were above the average for most farm barns. The ceiling height at the center was 9 feet 2 inches varying, with the gentle slope of the floor.

The entire stable housed 40 purebred cows - Holsteins at one end of the stable and Ayrshires at the other. Ayrshires were used throughout most of the tests.

The manger was 30 inches high in front and wood partitions extended to the top of the pipe rail of the chain-tie type of stall. The stall width was 4 feet and varied in length from 5 feet 8 inches to 5 feet 10 inches. The interior width of stable was 38 feet. It is evident that the extra width decreases light received at sides from center lamps, high-front mangers reduce light on floor of feed alley over that of raised alleys; and lack of stanchions adds a slight increment of light to feed alley over that of the average farm barn. Hence, like arrangement of lights as tested when used in farm barns and stalls of ordinary width and standard construction may be expected to give a slight difference in interior illumination in keeping with variations in construction.

All floor readings were taken at a fixed height of one foot at milking point in stalls, directly under lamps and midway between lamps. The feed alley readings were made 3 feet from the side wall. Lamps in

Table 1. Use of Light in Farm Dairy Stables with Respect to Sizes, Spacing and Positions of Lamps.

Barn	Lamp Spacing & Size: Spacing cows	Spacing feet	Size watts	Line volts	No.	No. of Stalls	Footcandles: Left Side 2/ Range		Total	Right Side Range		Total	Ave. per Stall	Alley Lamps and Footcandles: 1/ Litter No.	Range	Feed No.	Range
1	3	10.3	40	119.0	5	32	0.2	0.7	7.0	0.1	0.8	7.7	0.46	5	0.5-0.8	0	0.1-0.3
			60	118.0	7	32	0.4	1.3	15.0	0.3	1.5	14.9	0.93	5	1.0-1.5	2	0.6-1.5
			60	118.0	5	11	0.8	1.2	4.0	1.0	1.2	06.8	.96	5	---	0	---
			100	118.0	7	32	0.9	3.0	31.7	0.7	2.8	28.5	1.88	5	2.4-3.3	2	0.6-3.0
			100	118.0	5	32	0.8	1.8	21.9	0.6	1.6	22.2	1.38	5	2.0-2.5	0	0.3-0.5
6	4 to 4.5	17.5 18.8	25	118.0	4	28	0.1	0.4	3.2	0.1	0.4	2.6	0.20	4	0.2-0.7	0	0.0-
			40	117.5	4	28	0.2	0.5	5.2	0.3	0.5	4.9	0.36	4	0.7-1.0	0	0.1-0.1
			60	120.5	4	28	0.7	1.2	13.3	0.8	1.1	13.6	0.96	4	1.5-2.1	0	0.2-0.4
			100	119.5	4	28	0.8	1.6	17.6	0.7	1.5	16.7	1.23	4	2.5-3.4	0	0.4-0.5
8	4.5 to 5	15.8 17.5	60 3/	114.8	3	28	0.1	1.0	9.9	0.1	0.8	7.8 4/	0.63	3	0.9-1.5	0	0.2-0.3
			100	112.5	3	28	0.1	1.5	15.2	0.1	1.0	10.3	0.91	3	1.4-2.8	0	0.2-0.3
			150	111.5	3	28	0.1	2.5	23.7	0.1	1.7	17.0	1.45	3	2.4-4.0	0	0.4-0.5
			200 3/	109.5	3	28	1.7	3.7	34.6	0.1	2.5	25.2	2.13	3	3.5-5.5	0	0.6-0.8
14	6.5 to 6.3	22.0 22.7	60	120.5	3	34 5/	0.2	1.0	14.0	0.1	1.0	10.1	0.71	3	0.2-2.5	0	0.2-0.3
			100	119.5	3	34	0.3	2.1	24.1	0.1	1.7	17.5	1.22	3	0.5-5.7	0	0.4-0.4
17	5	20.0	60	---	5	32 6/	0.3	0.8	8.9	0.3	0.9	8.3	0.53	3	0.5-1.2	2	0.2-1.2

1/ Between and under lamps
2/ Sum of all stalls
3/ 115 volt lamps, others 120 volt
4/ Lights on one side, 1 foot off center
5/ 18 cows on left and 16 cows on right
6/ 17 cows on left and 15 cows on right

the litter alley were tried in the center, over the rear gutter line, under girders and 2 feet in front of girders. In some cases lamps were opposite and in other combinations staggered as shown on floor plan Fig. 4. Lamp spacings for 3, 4 and 5 cows were tried or 9, 12 and 15 feet apart. The total rated wattage varied from 120 to 800 with 3 to 8 lamps in use.

Presentation of Data

Table 1 shows the light readings obtained in the stables of some of the farm barns surveyed. These data are a fair sample of conditions with the lamp spacing varying from 3 to 6.5 stalls and size of lamps from 25 to 200 watts. These barns were approximately 34 feet in inside width and varied somewhat in ceiling height and wall finish. Barns 6 and 17 had high-front mangers and the others were of "sweep in" type.

For detailed comparisons, the differences in the conditions within the stable will have to be considered. Table 1 gives briefly a sample survey of the light conditions as found in the modern farm barns which meet all the requirements for shipping milk into the city of Washington. Barn number 1 was built in 1939. Barn 6 is typical of many new barns in Maryland, while 8, 14 and 17 are somewhat older.

Fig. 1 shows data obtained in two modern barns ranging from the smallest lamps of 25 watts to the largest of 200 watts. The story is made more complete by removing the old lamps and measuring other sizes as shown in Table 1 and Fig. 1. With no lamps in the feed alley

for several farm stables, the 60 watt lamp spaced in the central or litter alley at intervals of 4 stalls in stable 6F gave almost the same lighting at the milking point[4/] as did the 100 watt lamps spaced from 4-1/2 to 5 stalls in stable 8F with an average of slightly less than one footcandle. The variations of the individual stalls may be noted by reference to Fig. 1.

The feed alley readings for 100 watt lamps in stable 8F, with high front mangers, were less than those in 6F with sweep in type of manger. It is also of interest to note that a higher average illumination was later obtained (up to 4.06 footcandles) in several other tests, with different spacing but with the same total rated wattage or even less, in spite of the usual increased output of lumens per watt for the larger lamps. (See table 2.) The arrows shown in Fig. 1 and subsequent figures represent positions of readings. These arrows are omitted where the reading was taken directly under the lamps.

Fig. 2 shows somewhat similar comparison of lamp sizes, but with the vertical section taken across the stable. In Fig. 1 data for stable 8F are shown for stall position and a cross section of stable is shown in Fig. 2. Because of the central position of the litter carrier track in this stable, lamps on one side are one foot off center and the effect shows up in Fig. 2 and is present in Fig. 1. An exact comparison is not possible because of the variables such as reflecting surfaces of walls, height of ceiling and other minor construction factors.

4/For the most part reference to light readings in this paper are for the milking point in the stall and adjacent to the cow as otherwise noted.

Table 2. Tests of Lights in Experimental Barn with Varied Position and Size of Lamps, With and Without Reflectors. (Abridged)

Test	Lamp Spacing and Size: Spacing cows 3/	Size watts	Line volts	No.	Footcandles: Left Side Cows 1-10 2/: Min.	Max.	Total	Right Side Cows 11-20: Min.	Max.	Total	Ave. 1-20	Footcandles and Alley Lamps: Litter No.	Litter Range	Feed No.	Feed Range	Manger 1/ 2	4	6
1R	4C	100	118.5	4	0.7	1.2	10.5	0.8	1.5	10.7	1.06	4	1.5-4.5	0	0.0	0.5	0.3	0.2
4	Do	40	118.0	3	0.3	0.6	4.9	0.5	0.7	5.7	0.54	3	0.7-1.1	0	0.0	0.3	0.2	0.2
5	Do	40	---	7	0.3	0.9	5.5	0.3	0.7	4.9	0.52	3	0.7-1.0	2-2	0.4-2.0	2.5	1.0	0.5
6	Do	40	---	9	0.5	0.8	6.7	0.6	1.1	7.8	0.72	3	1.0-1.5	3-3	0.3-2.4	0.5	0.4	0.5
9	Do	60	119.0	3	0.5	0.8	6.8	0.5	0.8	6.8	0.68	3	0.7-1.8	0	0.0-0.0	0.2	0.2	0.3
11	Do	60	121.5	7	0.7	1.3	10.0	0.7	1.4	11.2	1.06	3	1.3-2.3	2-2	0.7-3.6	4.0	1.7	0.7
7	Do	100	---	3	1.4	2.1	16.5	0.8	2.1	15.5	1.60	3	3.0-4.7	0	0.0-0.3	0.1	0.2	0.3
8	Do	100	---	7	1.1	2.8	20.1	1.3	2.8	19.5	1.98	3	3.5-5.1	2-2	1.2-6.6	8.7	3.0	1.3
12	3C	60	---	4	0.7	1.1	9.2	0.8	1.2	10.3	0.98	4	1.9-3.3	0	0.1-0.1	0.4	0.2	0.3
14	3C	60	121.0	8	0.8	1.7	13.2	1.0	1.8	13.3	1.32	4	2.3-3.5	2-2	0.8-3.3	4.8	1.6	0.8
30	3C	100	119.0	4	1.0	2.6	19.3	1.3	2.7	20.9	2.01	4	4.1-5.7	0	0.2-0.4	1.2	0.9	1.4
19	5C	60	---	3	0.6	1.3	8.6	0.6	1.0	8.1	0.84	3	1.1-3.0	0	0.0	0.2	0.2	0.3
27	4S	40	---	6	0.6	1.2	9.6	0.4	1.3	8.5	0.90	6	1.5-1.7	0	0.1-0.2	0.3	0.5	0.4
28	4S	60	---	6	1.1	2.6	19.0	1.1	2.5	17.8	1.84	6	3.0-3.1	0	0.2-0.4	0.6	0.7	0.7
29	4S	100	---	6	1.2	5.2	33.8	1.6	4.7	32.4	3.31	6	5.5-5.8	0	0.4-0.6	1.0	1.0	1.1
36R	4S	60	---	6	0.9	3.3	22.6	1.2	3.2	20.5	2.16	6	3.5-3.7	0	0.3-0.3	0.7	0.8	0.7
37R	4S	100	119.5	6	1.1	6.1	39.5	2.3	6.2	41.8	4.06	6	5.2-6.3	0	0.5-0.5	1.3	1.2	1.3

1/ Readings taken at top of manger at feed alley; No. 4 at center of manger but 2 and 6 near partitions.

2/ Sum of meter readings for 10 stalls.

3/ "R" Reflectors or enclosing globes used.

4/ Letter "C" in this column denotes central spacing of lamps and "S" staggered lamps over gutter line. All stalls are 4 feet wide.

Each of the cross sections in Fig. 2 contains data on 100 watt lamps. It is of interest to study these together with those presented in Table 2. The lower cross section represents data obtained at the experimental barn and permits of a comparison of two arrangements of lamp spacings, that of 100 watt lamps in the litter alley centrally spaced, 3 cows or 12 feet apart, with that of the 4-cow staggered spacing and over the gutter line. Further discussion of this arrangement will follow.

The readings taken directly below the 100 watt lamp in the 3 sections are essentially equal for the upper and lower cross sections, but are noticeably lower in the middle cross section. High ceilings and low reflection factor are effective but not measured.

Cows Facing In Versus Out

It is difficult to locate stables in Maryland where the cows face a central feed alley, and the tests made in the few found were unsatisfactory for purposes of comparison. Low voltage made it necessary to discard the data from one of these. The data shown in Fig. 3 were obtained in two well-lighted stables, 1F and 19F. In stable 1F, Fig. 2, cows faced outward, and the lamps in the central feed alley were spaced 3 cows or 10-1/2 feet apart. In 19F the cows faced in. Both stables had "sweep in" type mangers. Stable 19F had exceptionally clean walls and ceiling with a high gloss white enamel finish above the window sills. The area below the sills was painted black. This stable also had concealed lamps in R. L. M. reflectors level with the ceiling line (at a height of 10 feet at the litter alley) and with a 4-cow spacing.

These are the major construction differences, yet it is obvious that illumination of the milking position in these two stables is quite different, being about 1/3 less with the cows facing out with all 3 sizes of lamps. In the case of cows facing in, the lamps and walls were closer to the milking position and the total wattage was higher. The differences shown in the feed alley are not significant.

Experimental Barn

Fig. 4, the floor plan of the experimental barn, shows the relative position of the stalls and lights for the different combinations. There were 56 sets of readings taken using the various combinations. The numbers shown in the litter alley refer to the lamp spacing with reference to number of cows. The circles show the position of the original lamps with enclosing globes, which were spaced a little over 4-1/2 stalls apart. The lamps spaced on the center line are designated by the letter "C" while those with the staggered arrangement have the suffix "S". In Table 2 reading positions in stalls and alleys are marked with arrows, except under the lamps.

Central vs. Staggered Arrangement

Curves shown in Fig. 5 permit a limited comparison of two arrangements of lamps and their effectiveness. Tests 29 and 30 show that the 100-watt lamps and the 4-cow staggered arrangement, give higher stall illumination than the 3-cow central arrangement. If we compare the averages it is noted that the six 60-watt lamps give almost the same illumination as that for 3-cow spacing using four 100-watt lamps.

Reflector Study

It is recognized that reflectors give an increased efficiency in light distribution downward which varies with their individual characteristic and cleanness. The reflectors provide ledges for collection of dust and as the reflecting surface becomes dirty their efficiency likewise decreases. When used in farm stables they are seldom cleaned. The prevalence of dirty reflectors is so common that their use is opposed by milk regulating authorities of the Washington milk shed. In one farm stable, reflectors were mounted on the side walls, but no value for this placement could be detected at the milking point in the stall.

In the experimental barn, glass enclosing bowls are regular equipment and increase the attractiveness of the stable. However, the data in Fig. 6 does not favor their use. The bottom chart compares them in the condition in which they were originally found with that after they had been cleaned and with bare lamps with the globes removed. The latter gave the best illumination. Referring to Fig. 6, the average footcandles for clean versus dirty glass shows no difference but the curves show that clean globes are better. The average data is unduly affected by cow No. 20 being out of line.

Standard 100-watt 14-inch shallow bowl reflectors were also tried and the results shown in curves at top of Fig. 6. Here again reference to the averages does not tell the complete story, although there is a difference of about 15 percent in favor of the use of reflectors for both 60- and 100-watt lamps.

Lamp Position

Having compared the efficiency of lighting arrangement with respect to staggered lights over the gutter with that of centrally placed lamps, it is of interest to compare two other positions with respect to the cow as shown in Fig. 7.

The upper set of curves using a 40-watt lamp revealed a higher illumination in the feed alley because of its nearness, when placed over the back of the cow and 2 feet in front of the girder. However, the shadows cast and the lower illumination at the milking point showed this position to be not very satisfactory and the position under the girder was even less effective. In fact, when the 100-watt lamps were tried this arrangement was so obviously undesirable that no further trials were made. However, these curves are inadequate to convey the true condition of the shadows which must be observed in the stable.

Dark vs. Light Colored Cows

It is of interest to note the characteristic difference between the two breeds which were studied in the same stalls by the interchanging of cows. The Holsteins for the most part were unusually black for the breed and the Ayrshires were mostly white, thus permitting a contrast of the two colors. Fig. 8 shows consistently higher footcandles at the milking position for the 3 sizes of lamps (40, 60 and 100 watts) and differs from 10 to 18 percent in illumination. Some individual Holsteins were 1 to 2 inches higher than the Ayrshires. There was considerable difference in weight in some stalls between the two breeds and only a slight difference in others. In stalls 16 and 20 the

difference was 500 and 400 pounds respectively while in stalls 11 and 18 the difference was 50 and 75 pounds. The difference in size appears to be a less dominant factor than that of color.

For convenience in comparison of light position test 56 of part D is superimposed on part C, making the contrast more evident for the two positions of lights with a 60-watt lamp. It is noted that the footcandles for the light-colored cows are in general higher than for the dark cows.

Summary

Most farmers desire good stable lighting and will use it if some one will show them how to obtain it. All stables require some artificial light at chore time. The observations of present common practices and the tests made with a view to improving them have been briefly reviewed in this paper. The studies are incomplete and the data not entirely analyzed, but the high lights of these tests have been presented.

Most of the comparisons have been made at the milking point, and feed-alley lamps have in many cases been omitted so as to reduce the variables. Adequate light at the rear of the cow is most important in premoting cleanliness of the cow and the production of clean milk.

In stables where the feed for individual cows is weighed more illumination in the feed alley is needed than that used in the ordinary stable. The feed alleys in the experimental barn used in these tests do not have lamps as regular equipment. The illumination provided by the center lamps is inadequate to give the desired satisfaction.

Tests 5, 8, 11 and 14 in the abridged Table 2 show how this condition may be improved.

Observations made show a need of 2 footcandles or more for close readings of the ordinary dairy scale. In the ordinary feed alley 0.3 to 0.5 footcandles or more are used but this is inadequate to enable one to distinguish the tines of a fork on top of a clump of hay, although the bright wood handle may be readily seen.

The majority of dairy farmers desire better lights in their stables. The Maryland survey indicates that many are satisfied with approximately 1 footcandle of light at the milking point. Our studies show that higher levels of illumination can be easily obtained with efficient use of 60- or 100-watt lamps. The difference in cost between poor and mediocre light and that of good lighting is so small that few will hesitate to improve their lighting if they are shown how they may do it.

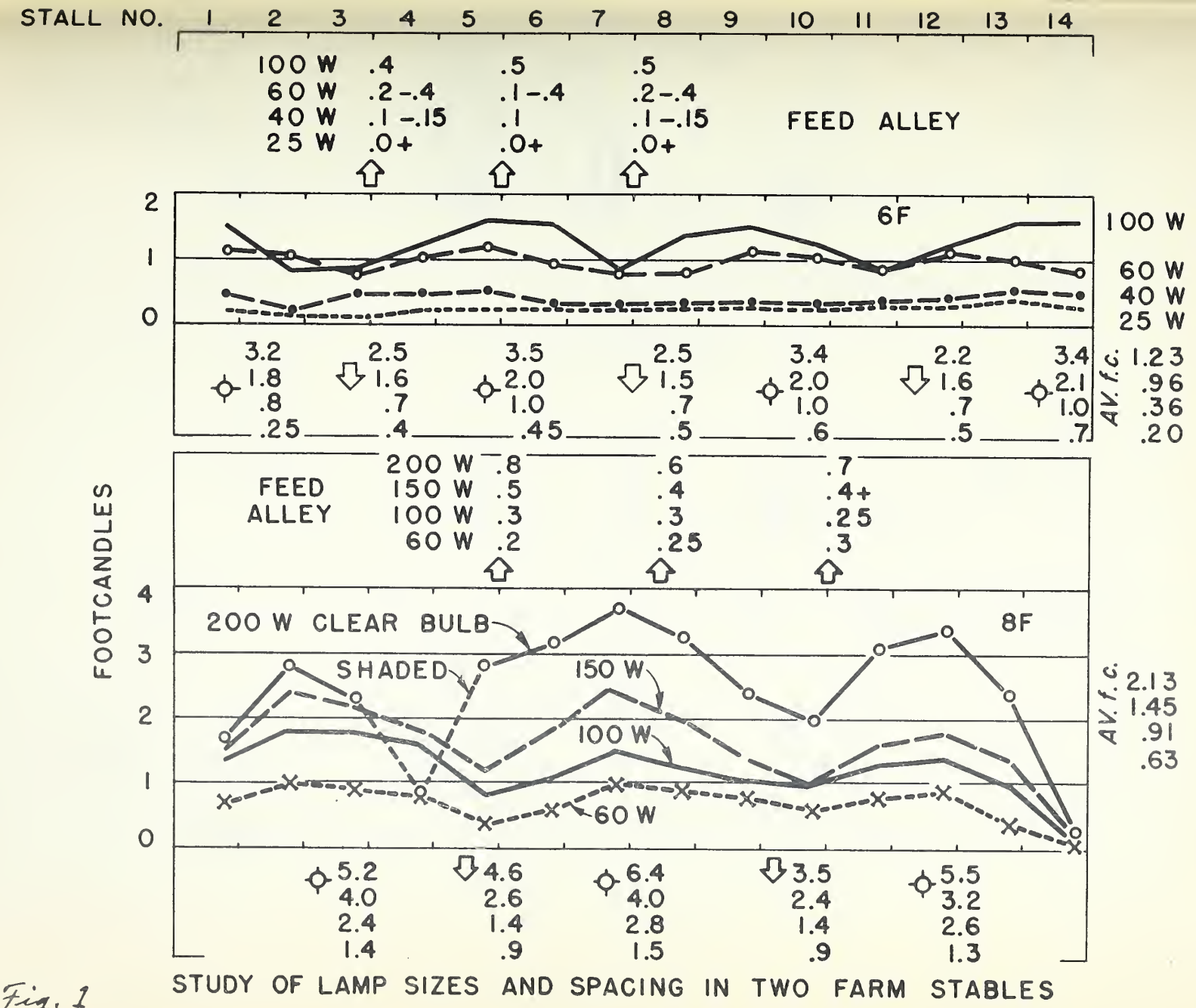
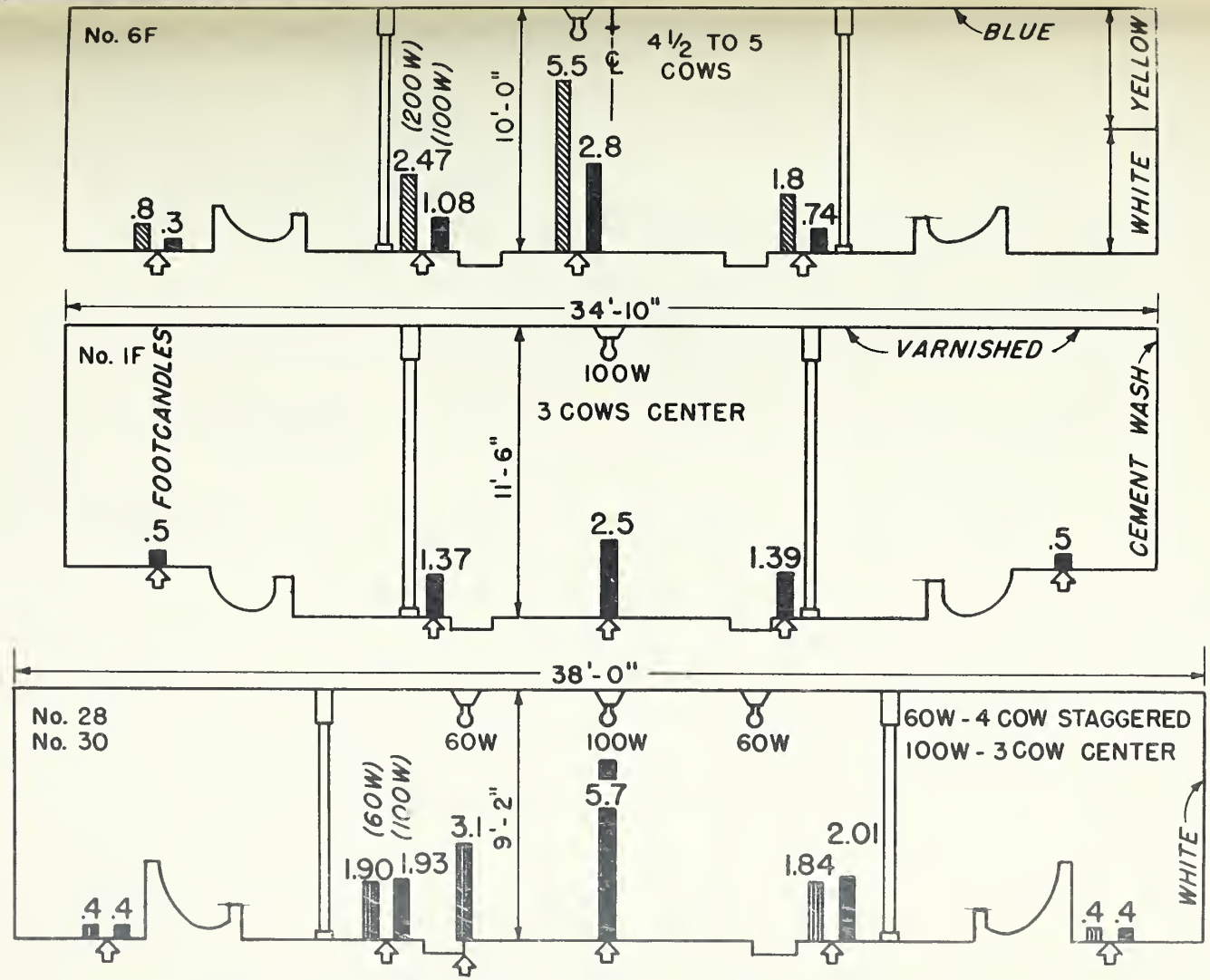
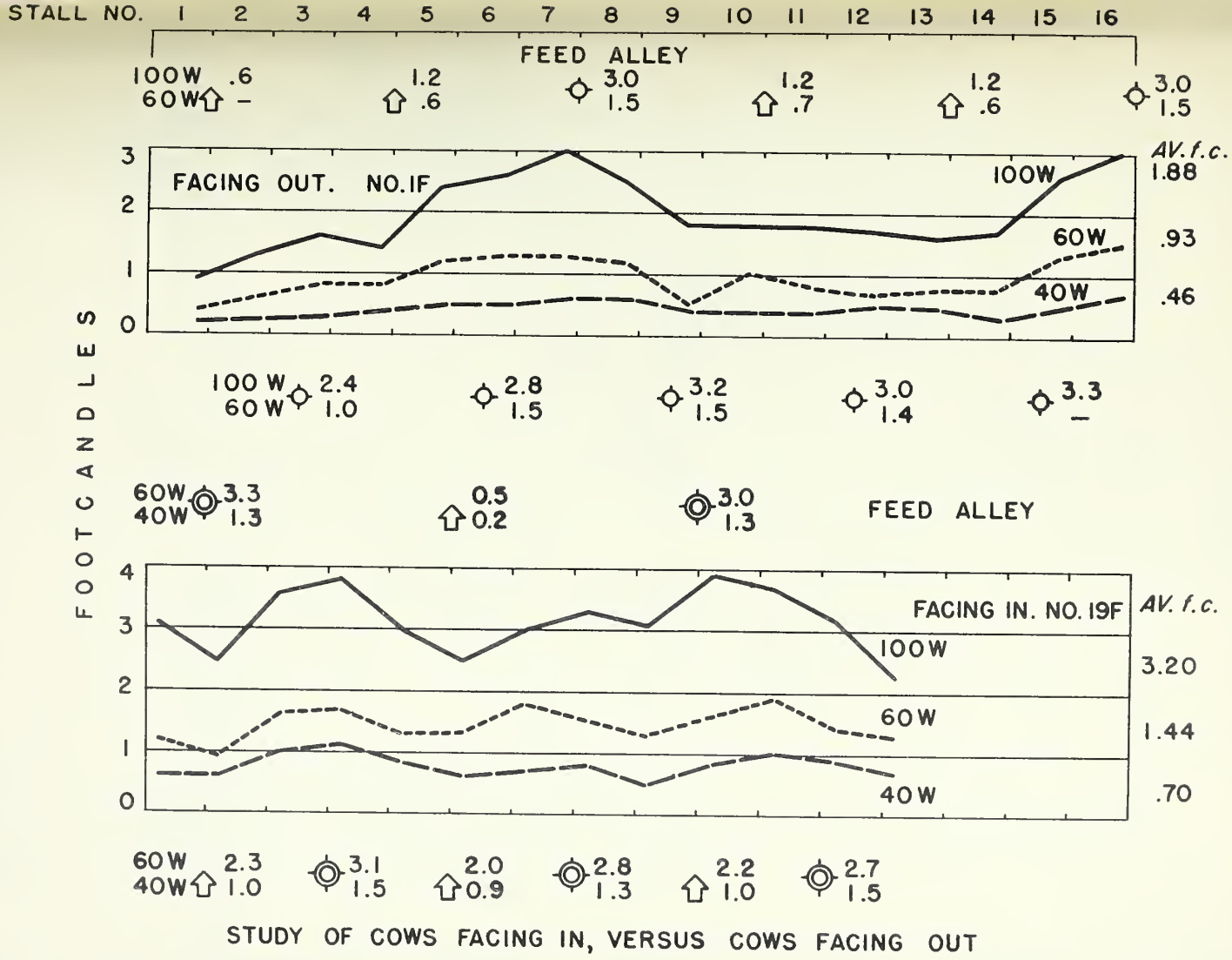


Fig. 1 STUDY OF LAMP SIZES AND SPACING IN TWO FARM STABLES



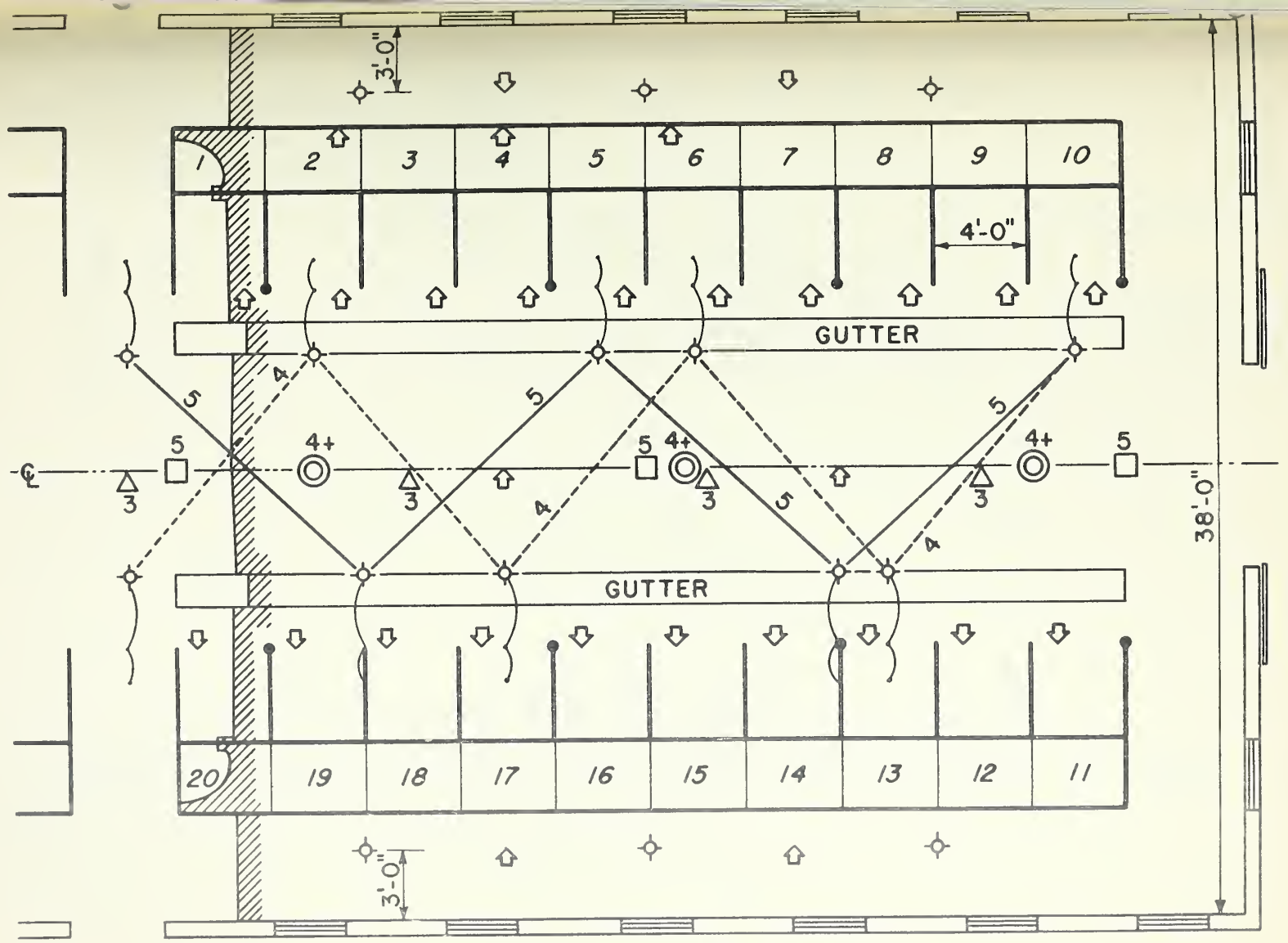
ILLUMINATION LEVELS IN VARIOUS POSITIONS IN THREE DAIRY STABLES

Fig. 2



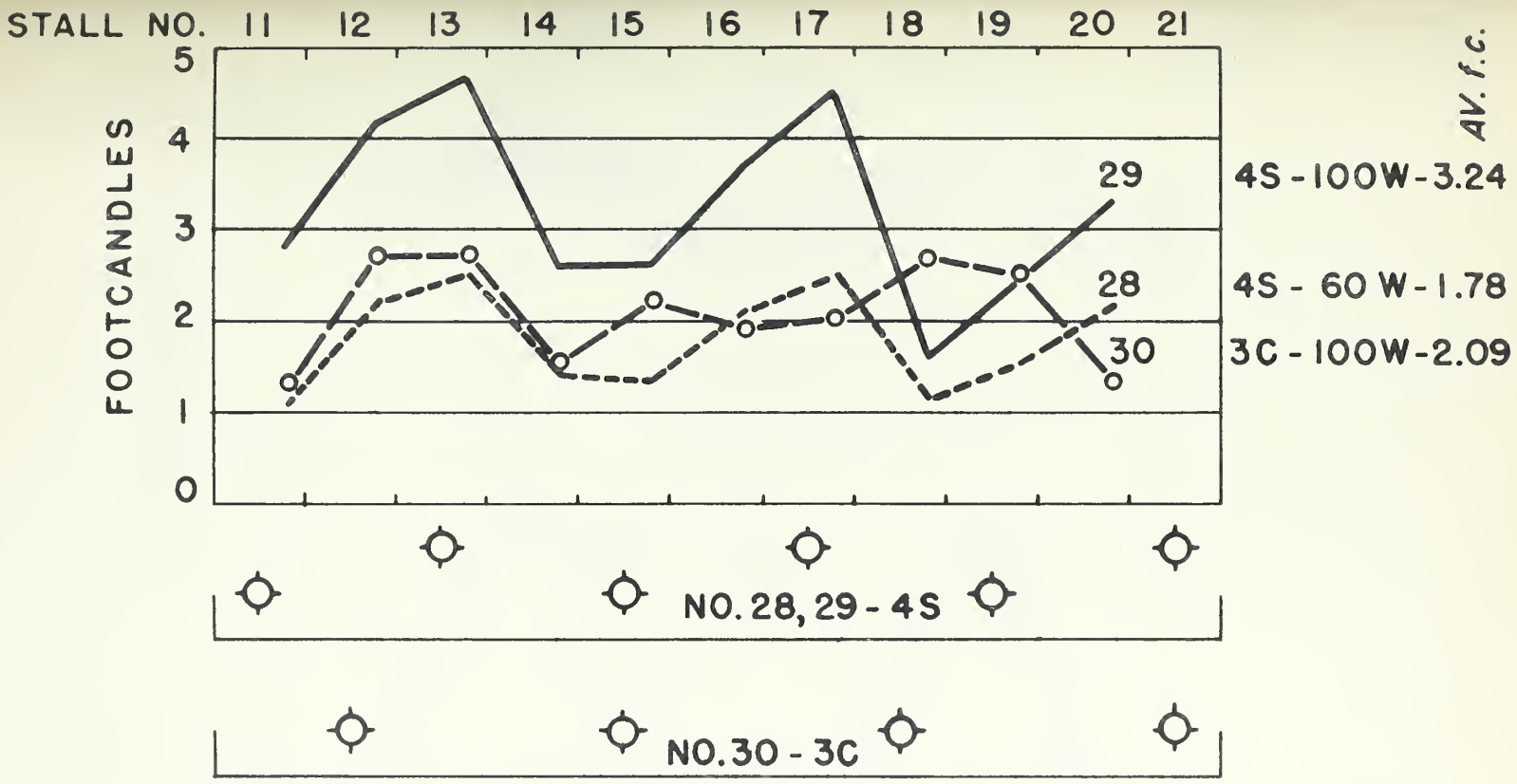
STUDY OF COWS FACING IN, VERSUS COWS FACING OUT

Fig. 3



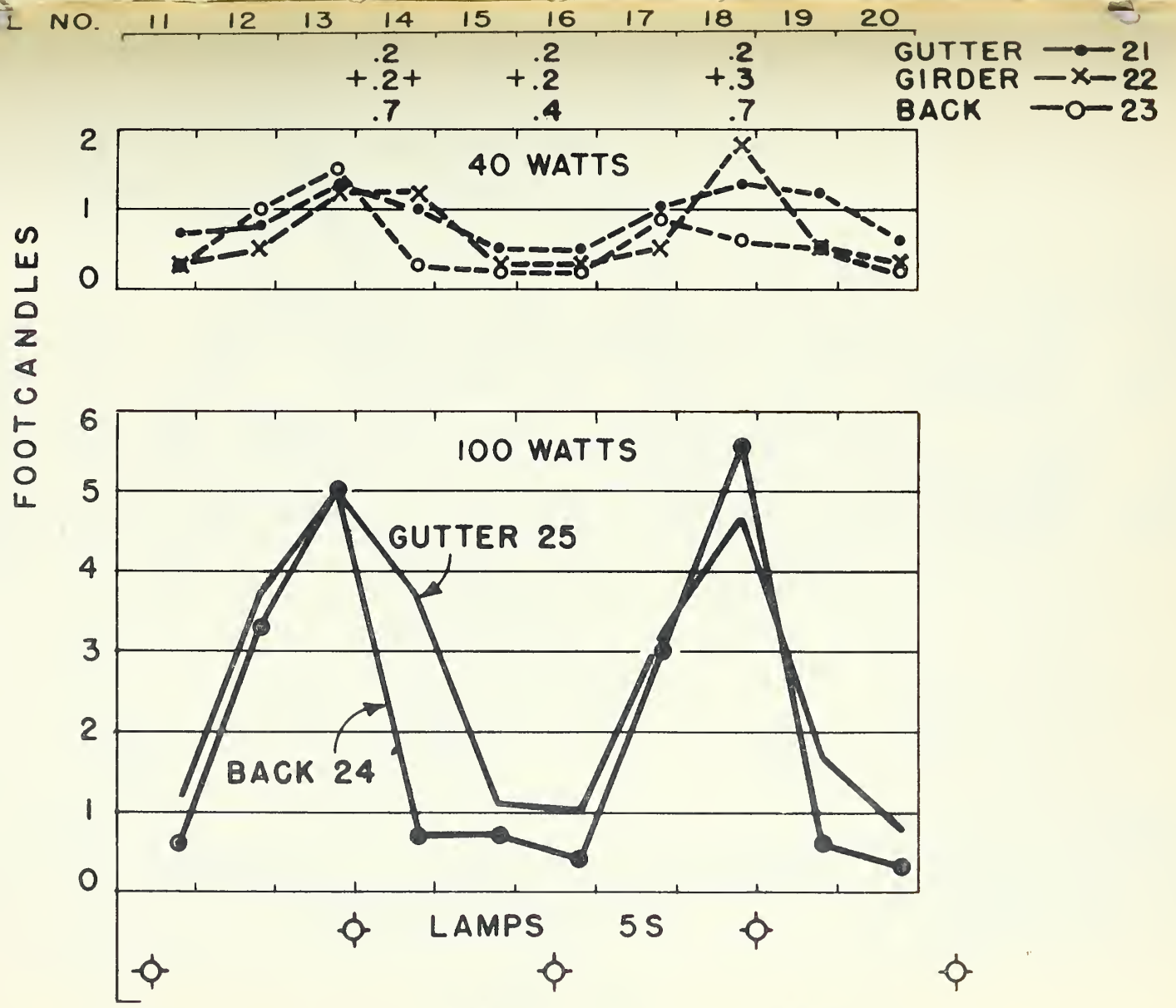
PLAN OF EXPERIMENTAL BARN
SHOWING POSITION OF LAMPS AND LIGHT
READING STATIONS INDICATED WITH ARROWS

Fig. 4



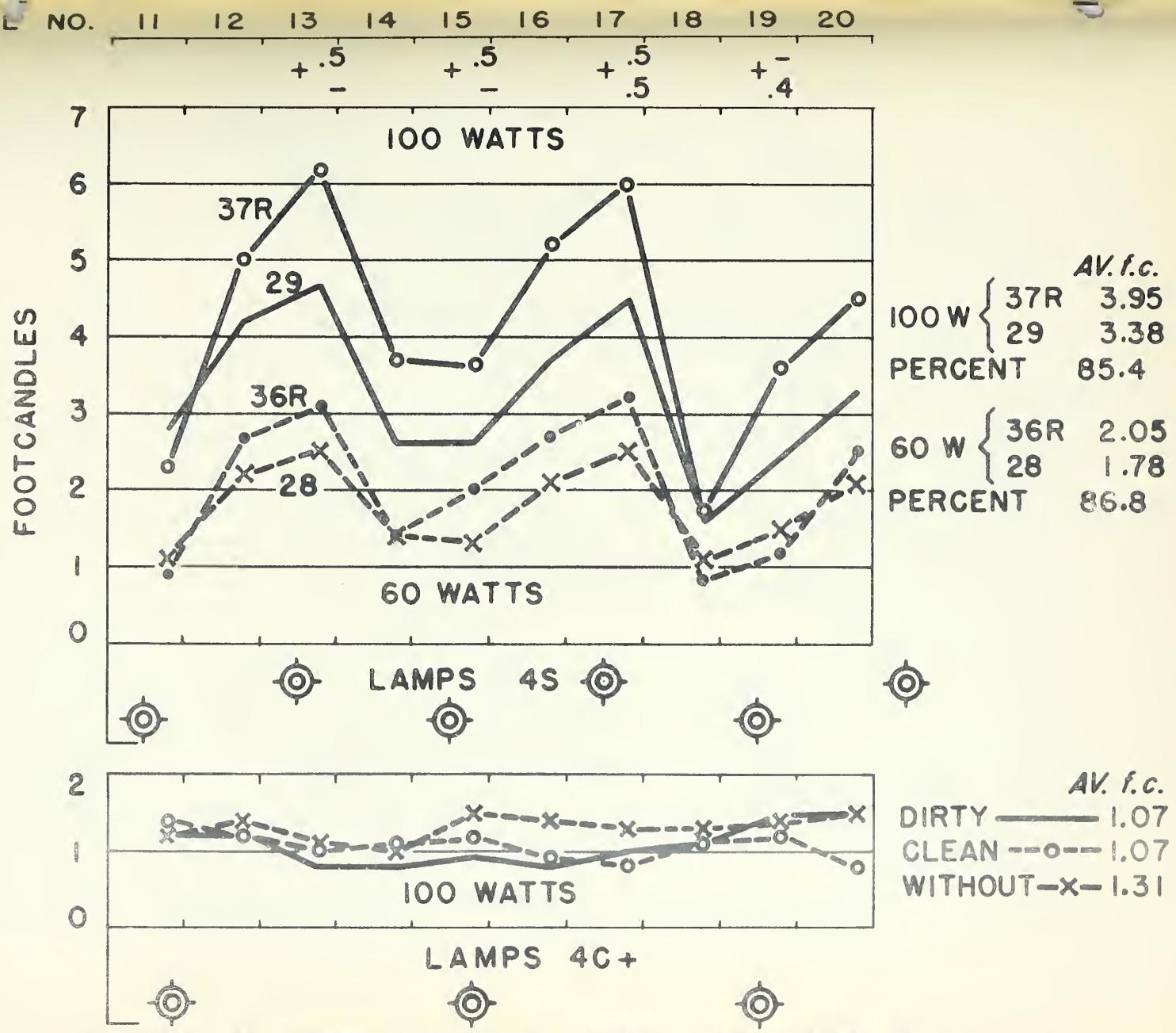
STUDY OF CENTRAL VERSUS STAGGERED ARRANGEMENT OF LAMPS

Fig. 5



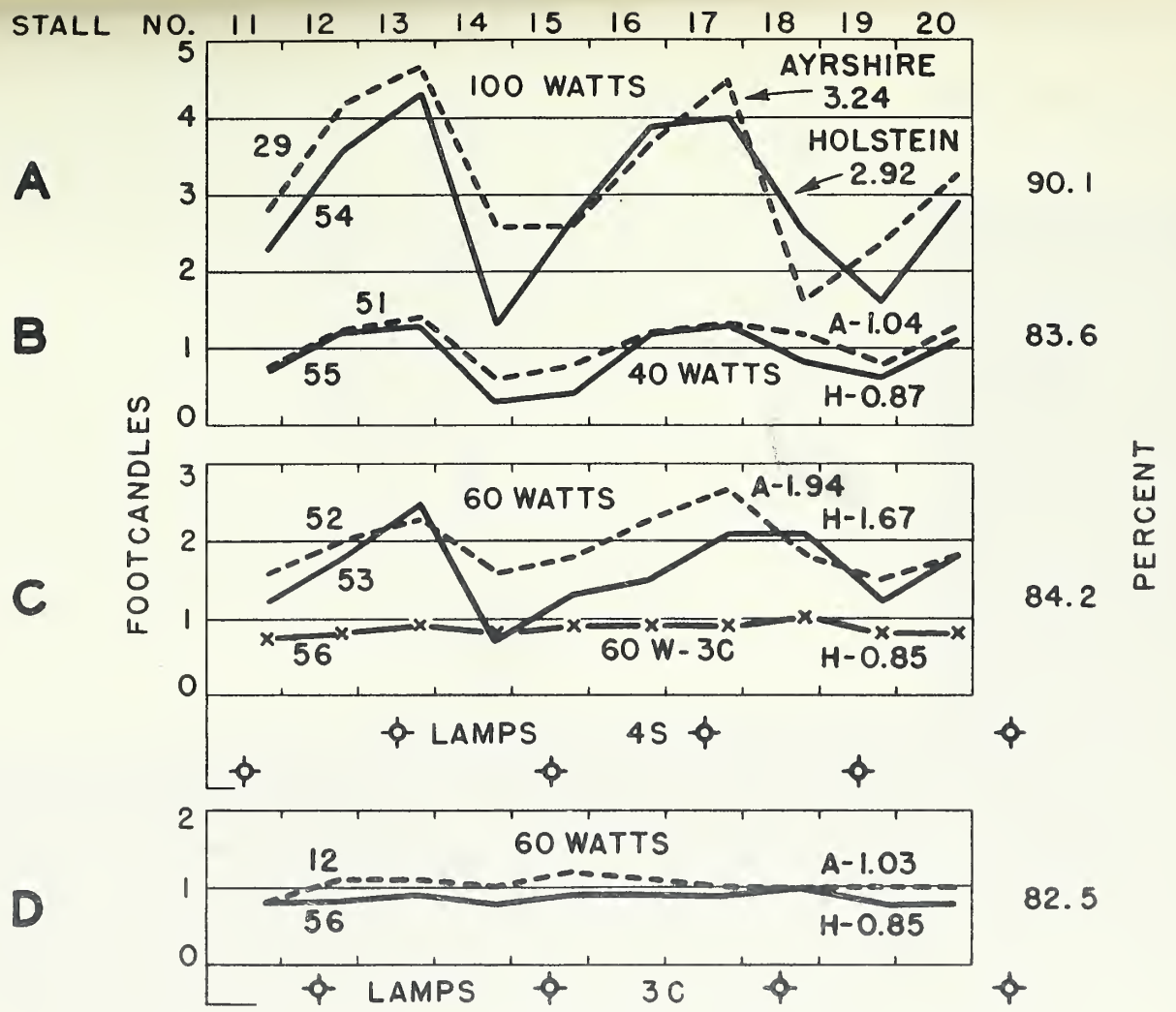
STUDY OF 14" SHALLOW REFLECTORS; ENCLOSING GLOBES; DIRTY OR CLEAN, AND BARE LAMPS

Fig. 6



STUDY OF LAMP POSITION OVER THE BACK OF THE COW; UNDER THE GIRDER, AND OVER GUTTER

Fig. 7



ILLUMINATION WITH DIFFERENT SIZES OF LAMPS
WITH DARK VERSUS LIGHT COWS IN THE STALLS

Fig. 8